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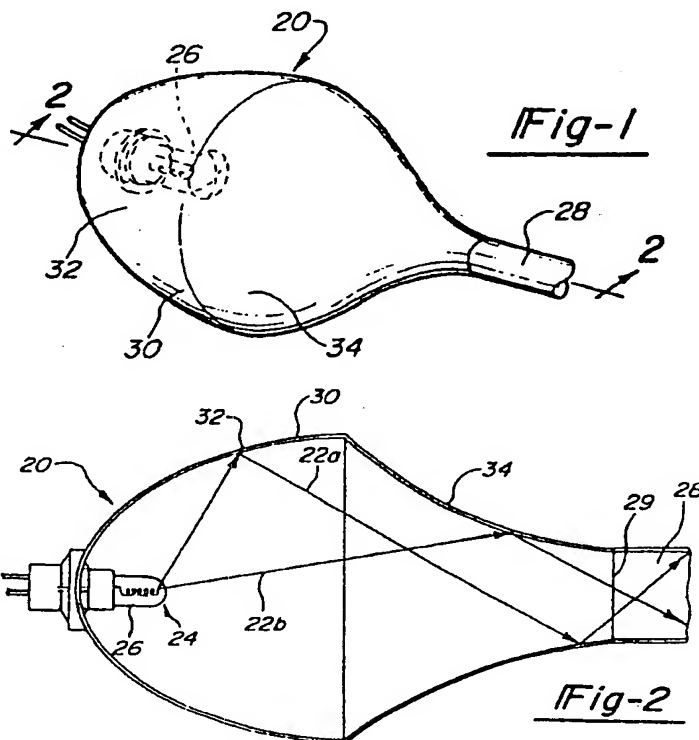
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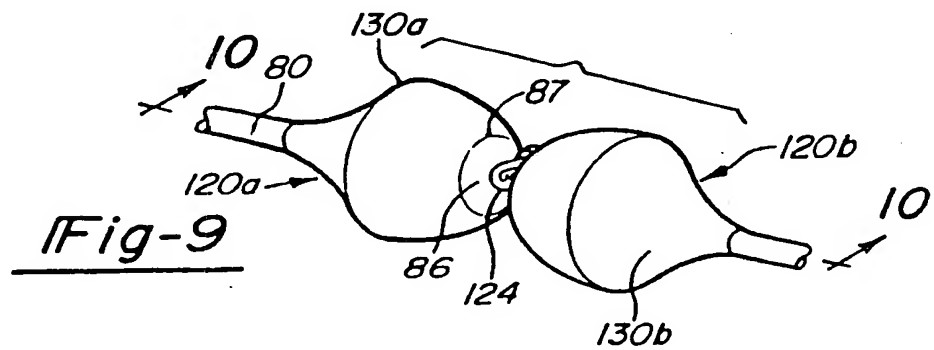
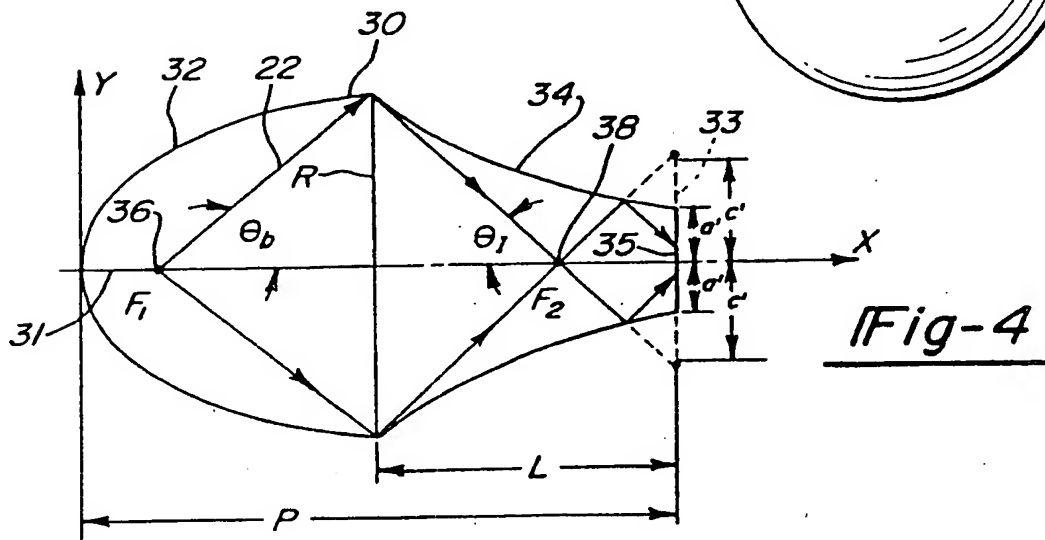
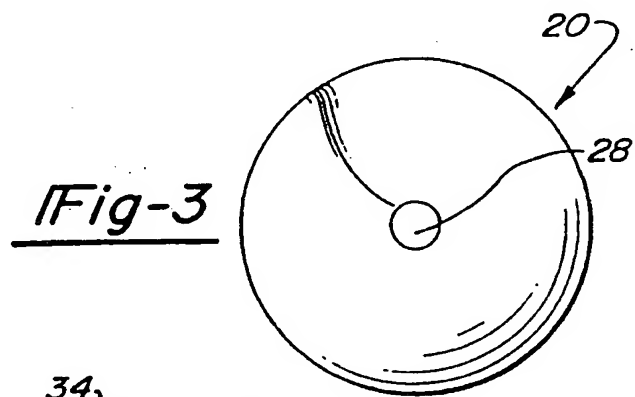
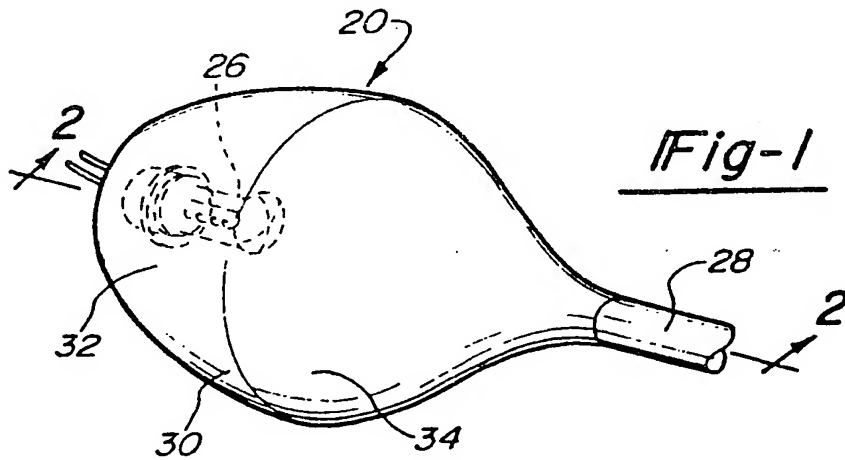
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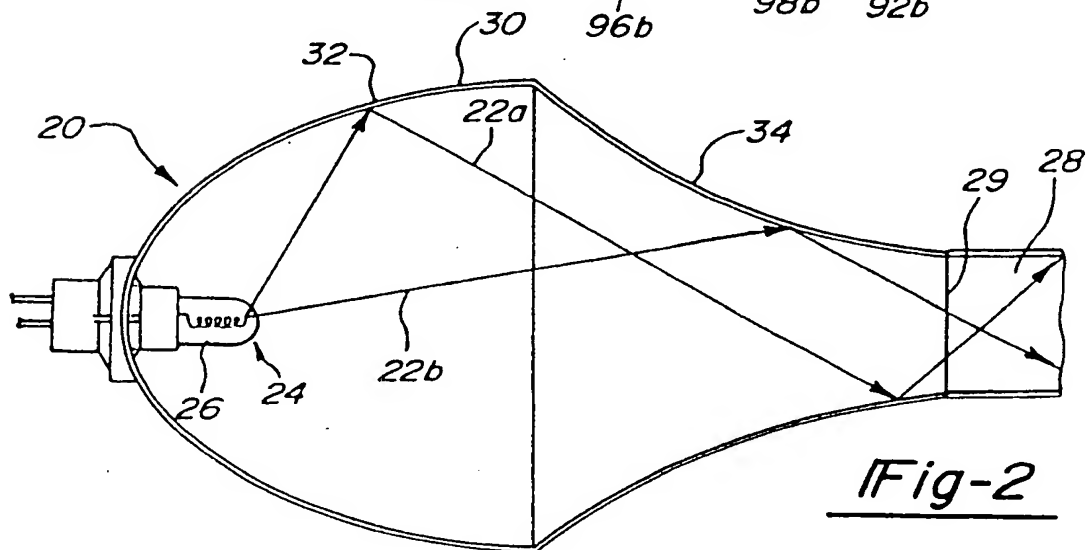
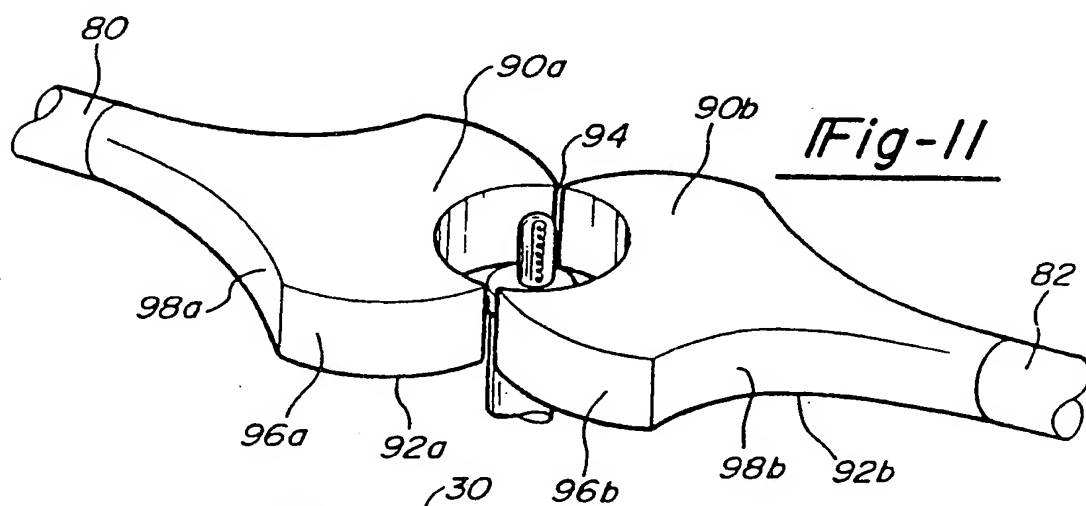
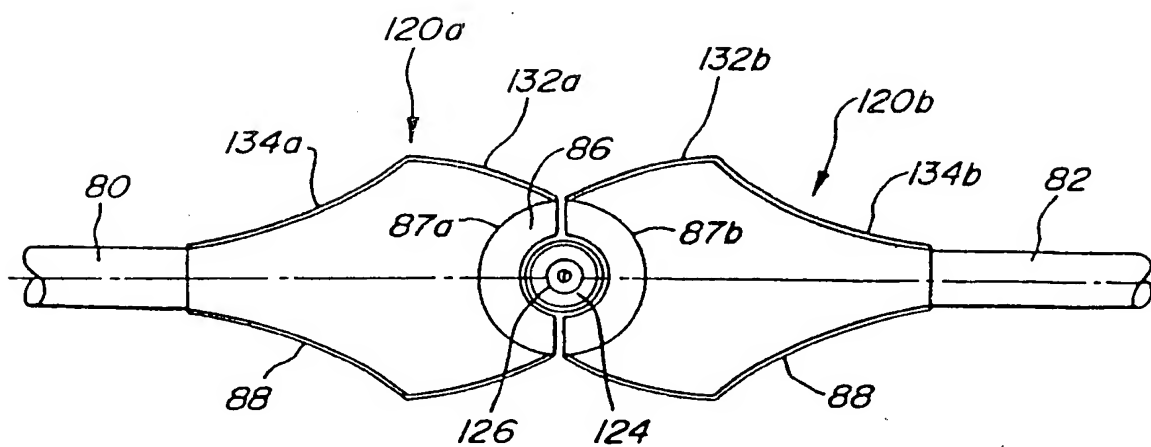
(54) Apparatus for collecting and transmitting light

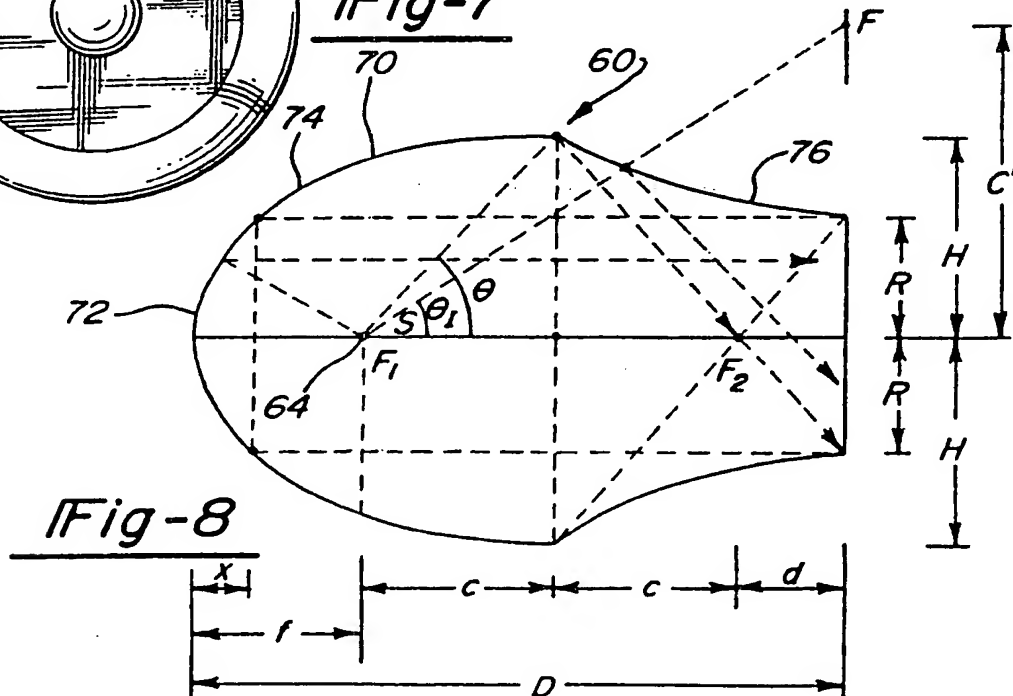
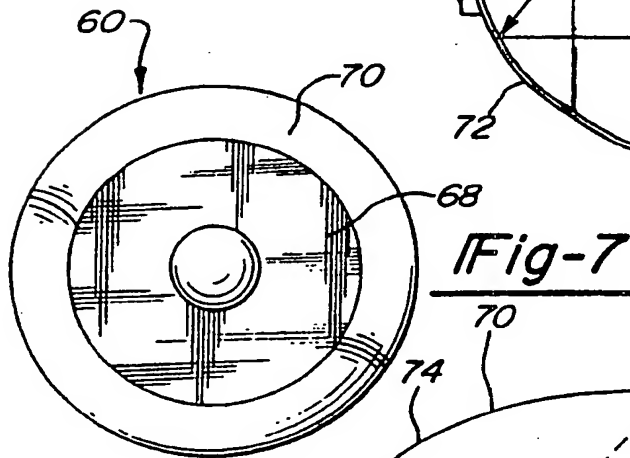
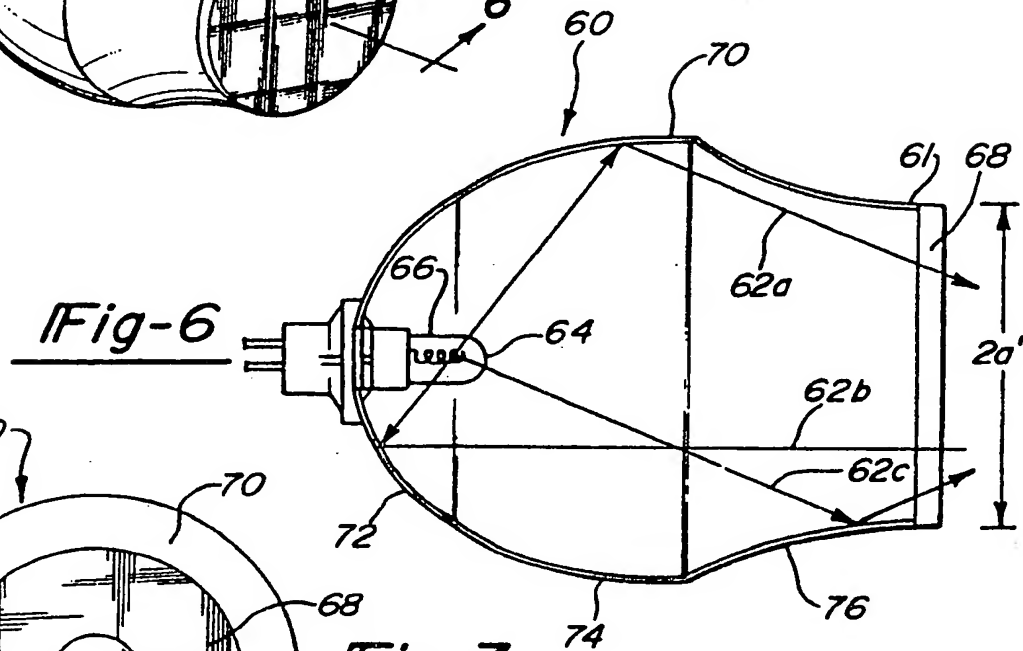
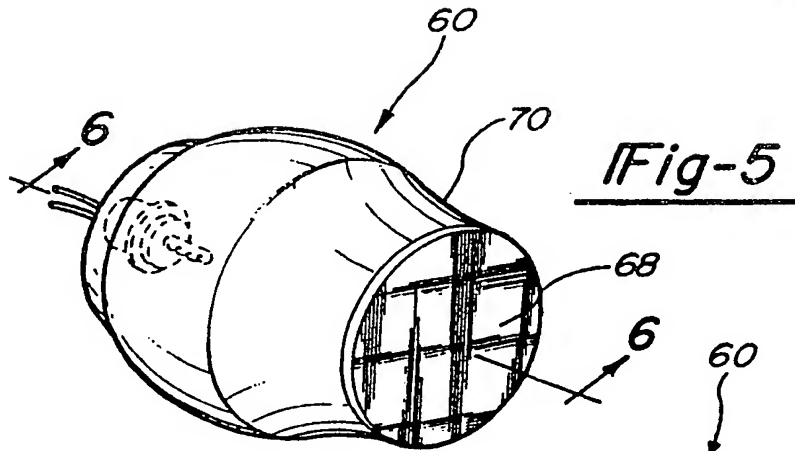
(57) An apparatus includes a reflective surface (30) for high efficiency collection, transmission and emission of light. Light collected by ellipsoidal and hyperboloidal portions (32, 34) of the reflective surface (30), is directed into a light guide (28). Additionally, a paraboloidal portion may be added and used in combination with a lens element to distribute the light reflected by the reflective surface in a beam pattern. When used as an emitter lens profile is smaller than the overall diameter of the reflective surface. When used as a collector (20) the reflective surface (30) receives and concentrates light onto the end of a light pipe.



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APPARATUS FOR COLLECTING AND TRANSMITTING LIGHT

The present invention relates generally to a lighting system for use with a vehicle and more specifically to an apparatus used to collect and transmit light.

5 Conventional vehicle lighting systems typically utilise a bulb and reflector combination. In a bulb and reflector combination, a filament of the bulb is placed at or near a focal point of the reflector. The focal point of a reflector is that point at which parallel rays of light meet
10 after being reflected by the reflector. Conversely light rays emanating from the focal point are reflected as parallel rays of light. Energy supplied to the filament radiates as light over a 4π steradian solid angle. A portion of the radiated light is collected by the reflector
15 and reflected outward. The outwardly reflected light is passed through a lens to form a light beam.

With the advent of light guides such as fiber optics, the ability to use a remote light source and a fiber optic light guide to transfer light generated at the remote light
20 source to a distant location became available. A system of reflectors and lenses is typically used to direct light emitted from the light source, such as a bulb filament, into the end of a fiber optic light guide. The amount of light that can be effectively directed into the fiber optic light
25 guide varies with respect to the numerical aperture of the fiber optic light guide. The numerical aperture is a number which corresponds to the acceptance angle; i.e. the critical angle at which light striking the end of the fiber optic light guide will enter the light guide. Light striking
30 the light guide at an angle greater than the critical angle will reflect off the face of the fiber optic light guide and become unusable light thus lowering the collection efficiency.

Until recently, the importance of the critical angle
35 with respect to the end of the fiber optic light guide was not recognised and the fiber optic light guide was simply brought closer to the light source. However, this resulted in a greater amount of light striking the end of the fiber

optic light guide at an angle greater than the critical angle resulting in a decreased collector efficiency. In an attempt to increase the amount of light entering the fiber optic light guide, reflective and focusing systems were
5 developed.

An example of such a system is disclosed in U.S. Patent Nos. 4,241,382 and 4,755,918. These patents disclose reflective systems having a combination of elliptical and spherical mirrors to direct and focus the light emitted from
10 a bulb filament onto the end of a fiber optic light guide. The light emitted from the source is reflected by a spherical reflector and returned through the source prior to striking an elliptical reflector which focuses the light onto the end of the fiber optic light guide.

15 Since losses occur at each reflective surface, each additional reflection reduces the efficiency of the apparatus. Also, when the light is reflected through the filament, additional losses occur due to the light ray striking the filament. The filament is not a point source,
20 thus each reflection of the light increases the deviation from the desired path of travel until the deviation becomes significant and the reflected light ray is no longer focused upon the fiber optic light guide. Finally, these systems tend to focus all of the light onto the small area of the
25 elliptical reflector. Since the light source or bulb filament is not a point source the system becomes very sensitive to filament size and location, resulting in greater angular deviation of the light ray.

Typically a greater intensity light source is used to
30 make up for any inefficiencies of a reflective system. However, even with a relatively efficient light source each watt of power supplied to the bulb filament results in only .25 watts of optical energy (light), and the remaining .75 watts is non-optical energy (heat). Thus the
35 use of a higher intensity light source results in excessive heat.

Therefore, it is desirable to have a highly efficient compact apparatus which collects and focuses light produced

by a bulb filament in a predetermined pattern onto the end of a fiber optic light guide and at angle less than the critical angle of the fiber optic light guide. It is further desired to avoid reflected and redirected light from passing back through the filament. The occurrences of reflection of the light rays should be kept to a minimum prior to entering the fiber optic light guide to reduce any additional losses due to reflection and defocusing of the light rays.

10 Accordingly, the present invention is a highly efficient compact apparatus for use in providing usable light in the form of a light beam or focusing the light emitted from a filament onto the end of a fiber optic light guide. In general, the apparatus includes a light source
15 for emitting light and a reflective surface having an ellipsoidal portion and a hyperboloidal portion wherein the reflective surface collects, focuses and distributes the light emitted by the light source. The light may be distributed in a predetermined beam pattern and used as a
20 vehicle headlight or the light may be focused onto the end of a fiber optic light guide for transmission to a distant location.

One advantage of the present invention is that a compact apparatus may be developed which provides for
25 efficient light collection and focusing upon a relatively small target or receiving area. An additional advantage of the present invention is the ability to obtain a greater amount of light from a lower wattage source which reduces both energy consumption and infra-red heat energy.
30 Additionally, the present invention reduces the number of reflections prior to the light ray being focused onto the end of a fiber optic light guide; thus improving the overall collection efficiency of the apparatus.

The invention will now be described further, by way of
35 example, with reference to the accompanying drawings in which:

FIG. 1 is a perspective view of an apparatus according to the present invention, illustrated for use with a fiber

optic light guide.

FIG. 2 is a sectional view taken along line 2-2 of FIG. 1.

FIG. 3 is a front view of the apparatus of FIG. 1.

5 FIG. 4 is a schematic side view of the apparatus of FIG. 1.

FIG. 5 is a perspective view of an apparatus according to the present invention illustrated as an illuminator for use with a vehicle.

10 FIG. 6 is a sectional view taken along line 6-6 of FIG. 5.

FIG. 7 is a front view of the apparatus of FIG. 5.

FIG. 8 is a schematic side view of the apparatus of FIG. 5.

15 FIG. 9 is a perspective view of a first alternative embodiment of the apparatus of FIG. 1.

FIG. 10 is a sectional view taken along line 10-10 of FIG. 9.

FIG. 11 is a perspective view of a second alternative
20 embodiment of the apparatus of FIG. 1.

Referring to the drawings and more particularly to FIG. 1-4 thereof, an apparatus illustrated as a collector 20 for collecting and focusing light rays 22 emitted by a light source 24, having a bulb filament 26, onto the end of a
25 fiber optic light guide 28 is shown. As illustrated, the collector 30 has a reflective surface 30 for collecting the light rays. The reflective surface 30 has ellipsoidal 32 and hyperboloidal 34 portions. It should be appreciated that the present invention provides a collector 20, having a
30 reduced length along the focal axis 31 (FIG. 4), which collects substantially all of the light emitted from the light source 24.

As shown in FIG. 2, light rays 22a-22b emitting from the light source 24 strike both the ellipsoidal portion 32
35 and hyperboloidal portion 34 of the reflective surface 30. The light rays 22a-22b are reflected from the ellipsoidal and hyperboloidal portions 32 and 34 of the reflective surface 30 toward an end 29 of the light guide 28. The

ellipsoidal 32 and hyperboloidal 34 portions focuses light rays 22a-22b onto the end 29 of the light guide 28 at an angle less than the acceptance angle of the light guide 28. It should be appreciated that focusing the light rays 22a-
5 22b in this manner increases the number of light rays entering the light guide 28 while decreasing the number of times each light ray is reflected to correspondingly limit reflection losses.

Reference now to FIG. 4, a schematic of the collector 20
10 is shown. The ellipsoidal portion 32 of the reflective surface 30 has a first focal point (F_1) 36 and a second focal point (F_2) 38. Placing the light source 24 at the first focal point (F_1) 36 of the ellipsoidal portion 32 causes light rays 22 emitted from the light source 24 to
15 focus at the second focal point (F_2) 38 of the ellipsoidal portion 32. A portion of the light reflected by the ellipsoidal portion 32 will be directed into the light guide 28 without any additional incidence of reflection. The remaining light will strike the hyperboloidal portion 34 of
20 the reflective surface 30. The hyperboloidal portion 34 concentrates light received from the ellipsoidal portion 32 onto the end 29 of the light guide 28. In addition to concentrating the light received from the ellipsoidal portion 32, the hyperboloidal portion 34 also receives and
25 reflects light directly from the light source 24. The addition of the hyperboloidal portion 34 improves the efficiency of the collector 20.

The configuration of the reflective surface 30 is determined based upon several predetermine parameters
30 including: the numerical aperture or acceptance angle (θ_f), the radius of the fiber optic light guide (a'), the radius (R) of the elliptical portion 32 of the reflective surface 30 and the angle (θ_b) that the light rays are emitted from the bulb filament. A standard bulb with or without a black
35 or non-reflective coating at the tip only emits light outward at an angle (θ_b) greater than 30° from the focal axis 31. From a practical standpoint those bulbs without a black tip still only emit light outward at an angle greater than

30° with respect to the focal axis due to the small or reduced end view (taken along the focal axis) of the filament.

From the foregoing predetermined parameters the following unknowns which define the ellipsoidal 32 and hyperboloidal 34 portions of the reflective surface 20, are determined: c' =focal point of the hyperboloidal portion 34, c =focal point of the ellipsoidal portion 32, a =the vertex of the ellipsoidal portion 32 and L =the length of the hyperboloidal portion 34.

The hyperboloidal portion 34 concentrates the light reflected by the ellipsoidal portion 32 by converting the low angle light rays striking the large area surface 33 (focal disc) defined by c' into high angle light rays striking a smaller area surface 35 (focal disc) defined by a' . Since the smaller area 35 and the maximum angle the light may strike the smaller area 35 are known, a' = radius of the fiber optic light guide 28 and θ_f = the maximum acceptance angle, the maximum angle of incidence (θ_1) of the light rays striking the large area surface 33 may be calculated by the following LaGrangian invariant equation:

$$a'^2 (1 - \cos \theta_1) = R^2 (1 - \cos \theta_i)$$

and

$$a'^2 \sin^2 \theta_{i/2} = R^2 \sin^2 \theta_{1/2}$$

and

$$\sin \theta_{1/2} = a' / R \sin \theta_{i/2}$$

therefore

$$\theta_1 = 2 \sin^{-1} \left[a' / R \sin \theta_{i/2} \right]$$

Once θ_1 is known, the remaining unknowns c' , c , a and L , which define the reflective surface 30, are determined by the following equations. The variables having a prime superscript represent coordinates of the hyperboloidal

portion 34 and unprimed or non-primed variables represent the coordinates of the ellipsoidal portion 32 of the reflective surface 30. Solving for the focal point (c') of the hyperboloidal portion 34 of the reflective surface 30:

$$\tan \theta_1 = \frac{R + c'}{L}$$

and

$$\frac{R^2}{a'^2} - \frac{L^2}{b'^2} = 1$$

solving for L

$$\frac{R^2 - a'^2}{a'^2} = \frac{L^2}{b'^2} \quad L^2 = \frac{b'^2}{a'^2} (R^2 - a'^2)$$

$$L = \frac{c'^2 - a'^2}{a'^2} (R^2 - a'^2)$$

$$L = \left(\frac{c'^2}{a'^2} - 1 \right) (R^2 - a'^2)$$

such that

$$\tan \theta_1 = \frac{(R + c') a'^2}{(c'^2 - a'^2) (R^2 - a'^2)}$$

simplifying and solving for c'

$$c'^2 - a'^2 = \frac{R a'^2}{(R^2 - a'^2) \tan \theta_1} + \frac{a'^2 c'}{(R^2 - a'^2) \tan \theta_1}$$

wherein

$$c'^2 - \frac{a'^2}{(R^2 - a'^2) \tan \theta_1} c' - \left[1 + \frac{R}{(R^2 - a'^2) \tan \theta_1} \right] a'^2 = 0.$$

Once c' is known, the shape or curvature of the hyperboloidal portion 34, which is a surface of revolution, can be determined by

$$\frac{y^2}{a'^2} - \frac{x^2}{b'^2} = 1 \quad \text{where } b'^2 = c'^2 - a'^2.$$

Solving for the ellipsoidal portion 32:

$$\frac{R}{\tan \theta_0} + \frac{R}{\tan \theta_1} = 2c$$

simplifying and solving for c

$$c = \frac{R}{2} \left(\frac{\tan \theta_1 + \tan 30}{\tan \theta_1 \tan 30} \right) \quad \text{wherein } \theta_1 = 30$$

5 The equation for an ellipse is

$$\left(\frac{x - a}{a} \right)^2 + \frac{y^2}{b^2} = 1 \quad \text{where } c^2 = a^2 - b^2$$

substituting for x and y

10

$$\left(\frac{\frac{R}{\tan 30} - c}{a} \right)^2 + \frac{R^2}{a^2 - c^2} = 1$$

simplifying and solving for a

$$(\sqrt{3} R - c)^2 (a^2 - c^2) + R^2 a^2 = a^4 - c^2 a^2$$

15

results in

$$a^4 - a^2 (c^2 + R^2 + [\sqrt{3} R - c]^2) + c^2 (\sqrt{3} R - c)^2 = 0.$$

Whereby (a) and (c) are the respective vertex and focal
20 point of the ellipsoidal portion 32 of the reflective
surface 30.

Following is an example of a reflective surface 30
configuration based on a predetermined set of parameters a',
f and R from which c', c, a and L may be determined.
25 Starting with a fiber optic light guide having a radius (a')
= 4mm, a numerical aperture $f = 40^\circ$ and an ellipsoidal
portion 32 having a radius (R) of 20mm, the unknowns c', c,
a and L defining the reflective surface 30 are calculated as
follows:

30

$$\theta_1 = 2 \sin^{-1} \left[\frac{4}{20} \sin \frac{40}{2} \right]$$

$$\theta_1 = 7.85$$

35

solving for c'

$$c'^2 - \frac{(4)^2}{(20^2 - 4^2)} (\tan 7.85) c' - \left[1 + \frac{20}{(20^2 - 4^2)} (\tan 7.85) \right]$$

5

$$(4)^2 = 0$$

$$c'^2 - .302 c' - 22.048 = 0$$

$$c' = 4.84$$

10

and

$$L = \left(\frac{4.84^2}{4.0^2} - 1 \right) (20^2 - 4^2)$$

$$L = 178$$

solving now for the focal points (c) and the vertices

15

(a) of the ellipsoidal portion

$$c = \frac{20}{2} \left(\frac{\tan 7.85 + \tan 30}{(\tan 7.85) (\tan 30)} \right)$$

$$c = 89$$

20

25

and

$$a^4 - a^2 \left(89^2 + 20^2 + [(\sqrt{3}) (20) - 89] \right) + 89^2 \left((\sqrt{3}) (20) - 89 \right)^2 = 0$$

$$a = 91$$

30

Therefore, the overall length (P) of the reflective surface 30 is determined by the following equation:

$$(a - c) + L + \frac{R}{\tan \theta_b} = p$$

wherein

$$P = (91 - 89) + 178 + \frac{20}{\tan 30}$$

35

$$P = 214.6 \text{ mm}$$

Turning now to FIGS. 5-8, the apparatus is illustrated as an emitter 60 for collecting and emitting the light rays 62a, b, c from a light source 64, such as a bulb element 66, through a lens 68. The emitter 60 includes a reflective
5 surface 70 including paraboloidal 72, ellipsoidal 74 and hyperboloidal 76 portions. FIG. 6 shows light rays 62a, 62b, 62c exiting the emitter 60 as usable light. As shown FIG. 6, the end 61 of the emitter 60 which emits the light rays 62a, 62b, 62c has a smaller diameter (2a') than the overall
10 diameter of the reflective surface 70. The present invention enables the development of low profile and highly efficient lights, while allowing a designer greater latitude with respect to the aerodynamic and aesthetic styling of a vehicle.

15 Referring now to FIG. 8, a schematic of the emitter 60 is shown. The configuration of the emitter 60 is determined using the following predetermined parameters: the packaging depth (D), the height of the emitter (2R) the radius (H) of the elliptical portion and the location of the two focal
20 points (F_1 , F_2) of the ellipsoidal portion 74. The focal point of the paraboloidal portion 72 coincides with the first focal point F_1 of the ellipsoidal portion 74 and that the light source 64 is placed at the focal point F_1 of both the parabolic 72 and elliptical 74 portions. Given the basic
25 dimensions of the emitter 60 packaging, a second focal point F_2 should be selected. Beginning with the basic equation of the curves to be resolved to obtain the paraboloidal 72, ellipsoidal 74, and hyperboloidal 76 portions.

30

35

5 $y^2 = 4fx$ (parabola)

$$\frac{(x - f - c)^2}{a^2} + \frac{y^2}{b^2} = 1 \quad (\text{ellipse})$$

where a, b are lengths of semi-major and minor axes and
10 c is the focal length of ellipse. Also

$$c^2 = a^2 - b^2$$

and $\frac{y^2}{a'^2} - \frac{(x - c' - d - f)^2}{b'^2} = 1$ (hyperbola)

15 wherein $b'^2 = c'^2 - a'^2$

and c' is the focal length of the hyperbola. If 2H is
the overall height of the collector and 2R is the exit
diameter of the collector

20 $\theta' = \tan^{-1} \left(\frac{c'}{2c + d} \right)$

θ_1 represents the angle of light that will be collected
by the hyperboloidal portion 76 and directed outward

25

through the lens 68. An emitter 60 designed in accordance
with the forgoing procedure is set forth below.

30 Starting with the following predetermined parameters:
an overall package height (2H) of 120mm, an emitter height
of 2R where R = 25mm, a chosen focal length of the parabola
f=30mm. The distance is given by $X = \frac{R^2}{4f} = 5.21\text{mm}$. The
focal length of the ellipse $c = \sqrt{a^2 - H^2}$. Setting, for
35 example a = 3H, c = 169.70mm. To send all the light
collected by the ellipsoid through the exit, the dimension d
is chosen as $d = \frac{RC}{H} = 70.71\text{mm}$. The focal length c' of the
hyperbola for this configuration is found to be

collected by the hyperboloidal portion 76 will also be directed towards the lens 68. To better control the spread of light at the exit, segmented reflected geometries (complex surfaces) can be used.

5 Referring now to FIGS. 9-11 a first alternative embodiment of a collector 120 is shown. Like parts of the collector 20 have like reference numerals increased by a factor of one hundred (100). FIG. 9 shows to solid collectors 120a, b made preferably from a transparent,
10 acrylic or polycarbonate material positioned adjacent a light source 124. The use of two collectors 120a, b allows the light rays to be transmitted through two separate individual light pipes 80, 82. The overall configuration of the reflective surface 130 a, b i.e., the ellipsoidal portion
15 132a, b and hyperboloidal portion 134 a, b is determined in accordance with the foregoing method. As shown in FIG. 10, the focal points of the elliptical portions 132a, b coincide with the centre of a removed spherical portion 86. The light source 124 is positioned at the focal point of the
20 ellipsoidal portions 132a, b. By placing the light source 124 at the focal point, the light generated by the light source 124 enters the left 120a and right half 120b of the collector 120 through the spherical surface 87a, b with close to a 90° incident angle to reduce any effects of
25 reflection which prevent the light entering the collectors 120a, b. A lower index of refraction material, called cladding 88, covers the entire surface of both the ellipsoidal portion 132a, b and the hyperboloidal portion 134a, b except for the spherical portion 86. The foregoing
30 embodiment provides a collector having a single input (light source) and multiple outputs (light guides) which can be used to transmit light to multiple remote locations.

FIG. 11 shows a second alternative embodiment of the collector 120a, b shown in FIG. 10 having a reflective
35 surface 130a, b including ellipsoidal 96a, b and hyperboloidal 98a, b side surface and planar upper and lower surfaces 90a, b, 92a, b. A light source 94 from which light rays are emitted to a predominately cylindrical form is

placed at the focal point of the ellipsoidal side surface 96a, b. The ellipsoidal 96a, b and hyperboloidal 98a, b side surface collects and focus the light emitted by the light source 94 onto the ends of the light guides 80, 82.

- 5 Such a collector results in a compact duration and highly efficient light collection system for transmitting light to a remote location.

An apparatus of the type disclosed herein collects substantially all of the light rays emitted from the light
10 source. The light may be distributed in a variable intensity pattern or as usable light by the apparatus in the form of an emitter or the apparatus may take the form of a collector for focusing the distributing light into a fiber optic light guide.

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CLAIMS

1. An apparatus for collecting and transmitting light comprising:
 - 5 a light source (24) emitting light; and
 - a reflective surface (30), including an ellipsoidal portion (32) and a hyperboloidal portion (34), to direct the light emitted by said light source (24).
- 10 2. An apparatus as claimed in claim 1, wherein said light source is positioned at a first focal point of said ellipsoidal portion.
3. An apparatus as claimed in claim 2, including a
15 light guide wherein said reflective surface directs said light into said light guide.
4. An apparatus as claimed in claim 3, wherein said ellipsoidal portion includes a second focal point positioned
20 within said reflective surface, such that said light passes through said second focal point prior to being directed into said light guide.
5. An apparatus as claimed in claim 3, wherein said
25 light guide includes a fiber optic light guide.
6. An apparatus as claimed in claim 1, wherein a lens placed adjacent said light source is used to direct the light emitted by said light source.
- 30 7. An apparatus as claimed in claim 1, wherein the hyperboloidal portion is defined in part by the following equation:

35
$$c'^2 - \frac{a'^2}{(R^2 - a'^2) \tan \theta_1} c' - \left[1 + \frac{R}{(R^2 - a'^2) \tan \theta_1} \right] a'^2 = 0$$

where c' = focal point of the hyperboloidal portion.

8. An apparatus as claimed in claim 1, wherein the ellipsoidal portion is defined in part by the following equation:

5
$$a^4 - a^2 (c^2 + R^2 + [\sqrt{3} R - c]^2) + c^2 (\sqrt{3} R - c)^2 = 0.$$

where a = vertex of the ellipsoidal portion.

9. An apparatus as claimed in claim 1, wherein said
10 reflective surface includes a paraboloidal portion.

10. An apparatus as claimed in claim 1, wherein said paraboloidal portion includes a focal point;

said ellipsoidal portion includes a focal point, said
15 paraboloidal portion and said ellipsoidal portion positioned such that their respective focal points coincide.

11. An apparatus as claimed in claim 10, wherein said paraboloidal and ellipsoidal portions include a focal axis,
20 said paraboloidal and ellipsoidal portions joined at a plane passing through the focal axis normal to the focal axis.

12. An apparatus as claimed in claim 9, including a means for focusing said directed light.

25

13. An apparatus as claimed in claim 12, wherein said means to focus includes a lens.

14. An apparatus as claimed in claim 10, wherein said
30 ellipsoidal portion includes a first and a second focal point the first focal point coinciding with said focal point to said paraboloidal section and the section focal point of said ellipsoidal section positioned outside of said means for focusing said light.

35

15. An apparatus for collecting and transmitting light comprising:

- a light source emitting light;
- a reflective surface having an ellipsoidal portion and
- 5 an hyperboloidal portion;
- said ellipsoidal portion having a focal point, said light source positioned at said focal point; and
- a light guide positioned adjacent an end of said reflective surface, said reflective surface collecting and
- 10 directed said light into said light guide.

16. An apparatus as claimed in claim 15, wherein said reflective surface is a solid body formed of a transparent material having an index of refraction, and an outer surface

15 of said solid body coated with a material having an index of refraction lower than the index of refraction of said transparent material.

17. A method of designing an apparatus for the

20 collection and transmission of light comprising:

- establishing a set of predetermined parameters;
- providing a reflective surface having a hyperboloidal portion and an ellipsoidal portion; and
- forming said hyperboloidal portion and said ellipsoidal
- 25 portion in accordance with said predetermined parameters.

18. A method as claimed in claim 17, wherein the step of determining the predetermined parameters includes the steps of determining the acceptance angle of a fiber

30 optic light pipe (θ_f); determining the radius of the fiber optic light pipe (a'); determining the radius of the ellipsoidal portion (R); determining the configuration of the hyperboloidal portion and the ellipsoidal portion by determining a focal point of the hyperboloidal portion

35 according to the following equation

$$c'^2 - \frac{a'^2}{(R^2 - a'^2) \tan^2 \theta_f} c' - \left[1 + \frac{R}{(R^2 - a'^2) \tan^2 \theta_f} \right] a'^2 = 0$$

and calculating the length (L) of the hyperboloidal portion
5 according to the following formula

$$L = \left(\frac{c'^2}{a'^2} - 1 \right) (R^2 - a'^2);$$

10 determining the distance between a first focal point of the
ellipsoidal portion and the mid point according to the
following equation

$$c = \frac{R}{2} \left(\frac{\tan \theta_i + \tan \theta_b}{\tan \theta_i \tan \theta_b} \right);$$

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calculating the overall length of the ellipsoidal portion by
the following equation

$$20 \quad a^4 - a^2 (c^2 + R^2 + [\sqrt{3} R - c]^2) + c^2 (\sqrt{3} R - c)^2 = 0$$

such that the overall length of the reflective surface
is given by the following equation $a - c \left(\frac{+L + R}{\tan \theta_b} \right)$; and

calculating the overall length (D) of the reflective
25 surface according to the following equation

$$D = (a - c) + L + \frac{R}{\tan \theta_b}.$$

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19. A method as claimed in claim 17, including the
following steps, providing a paraboloidal portion adjacent
said ellipsoidal portion wherein said paraboloidal and
ellipsoidal portions have a common focal point.

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20. A method as claimed in claim 19, wherein the step
of determining said predetermined parameters includes
determining the overall depth of the reflective surface

(D), determining the height of the reflective surface ($2a'$)
determining the radius of the ellipsoidal portion (R),
determining the position of a first and a second focal point
(F_1, F_2), and the step of forming said hyperboloidal and
5 ellipsoidal portions includes the steps of determining the
distance (A) from the vertex to the focal point of the
paraboloidal section according to the equation,

$$A = \frac{a^2}{4f_1}$$

10 determining the length of the ellipsoidal portion (B)
from the following equation and; $B = a = \sqrt{c^2 + b^2}$ wherein
 $b = R$ and $c = \frac{F_2 - F_1}{2}$ determining the vertex of the
15 hyperboloidal portion according to the following
equation

$$c'^2 = \left[\left(\frac{L^2 a'^2}{R^2 - a'^2} \right) + a'^2 \right]$$

20 wherein $L = D - B$.

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Relevant Technical Fields

- (i) UK Cl (Ed.L) F4R (RCAA, RFN, RL)
(ii) Int Cl (Ed.5) F21V 7/07, 7/08

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S I AHMAD

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Databases (see below)

(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

Documents considered relevant following a search in respect of Claims :-
1-20

(ii) ONLINE DATABASE: WPI

Categories of documents

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Category	Identity of document and relevant passages	Relevant to claim(s)
X	GB 2040431 (VEB CARL ZEISS JENA)	1, 2 at least
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